

# DOE Solar Energy Technologies Program Review Meeting

Denver, Colorado, October 25–28, 2004

Denver Marriott Tech Center Hotel

## Monday, October 25, 2004

7:30–8:30, *Continental Breakfast*

### Plenary Session I-A: Opening Session

Chair: Richard Matson

8:30–9:50 a.m.

- 8:30 Conference Welcome, Richard Matson, NREL
- 8:40 NREL Welcome, Larry Kazmerski, NREL
- 8:50 DOE Welcome, Richard King and Frank Wilkins (for Ray Sutula), DOE
- 9:10 SNL Welcome, Margie Tatro, SNL
- 9:20 SEIA Roadmap and Agenda, Rhone Resch, SEIA

9:50–10:20 a.m., *Coffee Break*

### Plenary Session I-B: Opening Session

Chair: Stan Bull

10:20–11:50 a.m.

- 10:20 Photovoltaics Subprogram Overview, Richard King, DOE
- 10:50 Solar Thermal Subprogram Overview, Frank Wilkins, SNL
- 11:10 €/kWh or kWh/\$?, Peter Johnston, Arizona Public Service

**Rappaport Award - 11:50 a.m.–12:00 p.m.**

12:10–1:40 p.m., *Lunch*

Speaker: Nathan Lewis, California Institute of Technology  
Scientific Challenges in the Development of Sustainable Energy

## PARALLEL ORAL SESSIONS

1:40–3:40 p.m.

### High-Performance PV I: Thin Films

Chair: Tim Gessert

- 1:40 High-Performance Photovoltaic Project Overview  
Martha Symko-Davies *et al.*
- 2:00 Advances in Polycrystalline Thin-Film Tandem Solar Cells  
Timothy J. Coutts
- 2:20 Growth and Characterization of CdZnTe and Cu(InGa)(SeS)<sub>2</sub> for Wide-Bandgap Solar Cells  
William N. Shafarman *et al.*
- 2:40 Properties of Surface-Modified CuGaSe<sub>2</sub> (CGS) Solar Cells with Improved Performance  
Jehad Abushama *et al.*

- 3:00 Progress in Thin-Film Si Bottom Cell for High-Performance Thin-Film Tandem Solar Cells  
Roger Aparicio *et al.*
- 3:20 Toward a Tandem Cell with All II-VI Semiconductors by Magnetron Sputtering  
Alvin Compaan

### **Exploratory PV I: Next-Generation Thin Films**

**Chair: Brian Gregg**

- 1:40 Polymer-Based Nanocomposites for Solar Energy Conversion  
Sean Shaheen *et al.*
- 2:00 Dye- and Semiconductor-Sensitized Nanoparticle Solar Cell Research at NREL  
Arthur J. Frank *et al.*
- 2:20 Ultra-High-Efficiency Excitonic Solar Cell  
Josef Michl *et al.*
- 2:40 Interface and Electrode Engineering for Next-Generation Organic Photovoltaic Cells  
Thomas Mason *et al.*
- 3:00 Band Structures and Optical Properties of Transparent Conducting Oxides: Cd<sub>2</sub>SnO<sub>4</sub>, Zn<sub>2</sub>SnO<sub>4</sub>, and CdIn<sub>2</sub>O<sub>4</sub>  
Su-Huai Wei *et al.*
- 3:20 Toward a Unified Treatment of Electronic Processes in Organic Semiconductors  
Brian A. Gregg *et al.*

### **Solar Heating and Lighting**

**Chair: Tim Merrigan**

- 1:40 Low-Cost Solar Water Heating Systems  
Jay Burch *et al.*
- 2:00 Durability of Polymeric Glazing and Absorber Materials  
Gary Jorgensen *et al.*
- 2:20 Next-Generation Polymer Solar Heating Systems  
Sue Mantell *et al.*
- 2:40 Overview of Solar Heating Industry Assistance Program  
Greg Kolb *et al.*
- 3:00 Recent Advances in Hybrid Solar Lighting R&D  
Jeff Muhs *et al.*
- 3:20 Solar Domestic Hot Water Systems Analysis  
Jay Burch *et al.*

3:40–4:00 p.m., *Coffee Break*

### **Poster Session I**

**4:00–6:00 p.m.; Reception at 5:00 p.m.**

#### **Solar Heating and Lighting**

- P001 SunCache Residential Solar Water Heating System – Phase V  
Dick Bourne *et al.*
- P003 Polymer ICS System Development  
Richard O. Rhodes *et al.*
- P005 Quality Assurance via Certification; Development and Maintenance of Testing Standards for Solar Energy Systems  
Byard Wood *et al.*

#### **Exploratory PV**

- P007 Coadsorbent-Induced Band Edge Shift in Dye-Sensitized TiO<sub>2</sub> Solar Cells  
Nathan R. Neale *et al.*
- P009 Effect of Nonideal Statistics on Electron Diffusion in Dye-Sensitized TiO<sub>2</sub> Solar Cells  
Jao van de Lagemaat *et al.*
- P011 Influence of the Electrolyte on the Performance of Dye-Sensitized TiO<sub>2</sub> Solar Cells: Band Edge Movement and Surface Shielding  
Nikos Kopidakis *et al.*
- P013 Correlation of Morphology and Device Performance in Inorganic-Organic; TiO<sub>2</sub>-Polythiophene Hybrid Solid-State Solar Cells  
Luke Robertson *et al.*
- P015 PV-Powered Hydrogen Production from the Electrolysis of Water  
Douglas Ruby *et al.*
- P017 Fabrication, Characterization, and Simulation of Solar Cells  
David Zubia *et al.*
- P019 Development of Quantum Dot-Sensitized ZnO and TiO<sub>2</sub> Nanorod Array Solar Cells  
Dawit Jowhar *et al.*
- P021 DOE-NREL Minority University Research Associates Program  
Fannie Posey-Eddy
- P023 PV Education and Research at Southern University  
Kara Broussard *et al.*
- P025 Generating Hydrogen through Water Electrolysis Using Concentrator Photovoltaics  
Robert McConnell *et al.*
- P027 Exploratory Research for New Solar Electric Technologies  
Robert McConnell *et al.*
- P029 Modeling and Control of High-Concentrator Photovoltaics for Hydrogen Production for Fuel Cells  
Robert Sowah *et al.*

## High-Performance PV

- P031 Identification of Critical Paths in the Manufacturing of Low-Cost, High-Efficiency CGS/CIS Two-Junction Tandem Cells  
Oscar Crisalle *et al.*
- P033 Determining Hole Carrier Mobilities Directly in Working CIGS Photovoltaic Devices  
J. David Cohen *et al.*
- P035 Novel Polycrystalline Thin-Film Solar Cells  
Eric Harmon *et al.*
- P037 InGaP/InGaAs/Ge Triple-Junction, High-Concentration Solar Cell Development at Emcore Photovoltaics  
Mark Stan *et al.*
- P039 InGaN Solar Cells  
Christiana Honsberg *et al.*
- P041 Toward 40%-Efficient Mechanically Stacked III-V Terrestrial Concentrator Cells  
Lewis M. Fraas *et al.*
- P043 Advances in III-V Heterostructures and Solar Cells on SiGe/Si Substrates  
Steven A. Ringel *et al.*
- P045 A Scalable High-Concentration PV System  
Stephen Kusek
- P047 Recrystallization of Germanium on a Ceramic Substrate  
Jim Rand
- P049 Enhanced-Depletion-Width GaInNAs Solar Cells Grown by Molecular-Beam Epitaxy  
Aaron J. Ptak *et al.*
- P051 An On-Sun Comparison of GaInP<sub>2</sub>/GaAs Tandem Cells with Top Cell Thickness Varied  
William E. McMahon *et al.*
- P053 Integrating Deposition, Processing, and Characterization Equipment within the National Center for Photovoltaics  
Brent Nelson *et al.*
- P055 Electron Microscopy Studies of GaP(NAs) Grown on Si  
Andrew Norman *et al.*
- P057 Electron Traps Detected in p-Type GaAsN Using Deep-Level Transient Spectroscopy  
Steve Johnston *et al.*
- P059 Correlation of DLTS and Performance of GaInNAs Cells  
Sarah R. Kurtz *et al.*

## Thin Films: CIS and CdTe

- PO61 CdTe: How Thin Can It Be and How Does Chloride Activation Change Grain Boundaries?  
Alvin D. Compaan *et al.*

- P063 Impurity Effects in Two-Step Processing of CIGS Solar Cells  
Harish Sankaranarayanan *et al.*
- P065 Contact and Stability Studies of CdTe Solar Cells  
Chris S. Ferekides *et al.*
- P067 CdTe and CIGS Numerical Simulations: When Are They Helpful?  
James Sites *et al.*
- P069 Local J-V Curves from LBIC Measurements  
Tim Nagle *et al.*
- P071 Effect of CdTe and CIGS Thickness on Cell Efficiency: Experiment Versus Simulation  
Alan Fahrenbruch
- P073 Development of Large-Area CIGSS Thin-Film Solar Cells  
Neelkanth G. Dhere *et al.*
- P075 Defect Physics and Chemistry in Thin-Film CdTe Solar Cells  
Tim R. Ohno *et al.*
- P077 Study of Deep Electronic States in CdTe Solar Cells with Capacitance Transient Measurements  
Fred H. Seymour *et al.*
- P079 Defect Studies of CdTe Cells Using Spatially and Spectrally Resolved Electro-Optical Methods  
Scott Feldman *et al.*
- P081 Non-Uniformities in CdS/CdTe Cells Deposited on Buffer Layers  
Joseph Beach *et al.*
- P083 Multiple-Wavelength, Near-Field Scanning Optical Microscopy Study of Thin-Film Polycrystalline Solar Cells  
John Yarbrough *et al.*
- P085 Advances in Continuous In-Line Processing of CdS/CdTe Devices: Stability and Scale-Up  
W.S. Sampath *et al.*
- P087 Large-Area CIGS Films and Modules Produced by a Hybrid Process, and High-Performance TCOs  
Alan E. Delahoy *et al.*
- P089 Outdoor Monitoring of Thin-Film PV Modules in Hot and Humid Climate  
W. Dan Turner *et al.*
- P091 Fabrication of CIGS Solar Cells via Printing of Nanoparticle Precursor Inks  
Vijay Kapur *et al.*
- P093 Liquid-Phase Deposition of CuInSe<sub>2</sub> Thin Films  
Jonathan Cowen *et al.*
- P095 Formation of Chalcogen-Containing Plasmas and Their Use in Synthesis of Photovoltaic Absorber Layers  
Colin Wolden *et al.*

- P097 Nanostructure and Nanochemistry of Cu(In,Ga)Se<sub>2</sub> Materials  
Changhui Lei *et al.*
- P099 Application of Combinatorial Tools for Solar Cell Improvement—New High Performance Transparent Conducting Oxides  
John Perkins *et al.*
- P101 Barrier Coatings for Thin-Film Solar Cells  
Larry Olsen *et al.*
- P103 XPS and UPS Studies of Thin-Film PV Materials Modified by Reactions in Liquids  
Craig Perkins *et al.*
- P105 In-Situ Investigation on Reaction Mechanism and Kinetics of CuInSe<sub>2</sub> Formation from Cu-In/Mo/Glass Precursor during Selenization  
Woo Kyoung Kim *et al.*
- P107 Pulsed-Laser Annealing and Rapid Thermal Annealing on CIGS Solar Cells  
Xuege Wang *et al.*
- P109 Growth and Characterization of Zn<sub>x</sub>Cd<sub>1-x</sub>S Buffer Layers by Chemical Bath Deposition for CuGaSe<sub>2</sub> and Cu(In,Ga)Se<sub>2</sub> Solar Cells  
Jiyon Song *et al.*
- P110 Spatially Resolved Studies of Grain-Boundary Effects in Polycrystalline Solar Cells Using Micro-Photoluminescence and Near-Field Microscopy  
Steve Smith *et al.*
- P111 Non-Vacuum Processing of CIGS Solar Cells  
Chris Eberspacher *et al.*
- P112 Conductive Atomic Force Microscopy of CdTe/CdS Solar Cells  
Helio Moutinho *et al.*
- P113 Raman Studies of Nanocrystalline CdS:O Film  
Yong Zhang *et al.*
- P114 Study of Potential Cost Reductions Resulting from Super-Large-Scale Manufacturing of PV Modules  
Marvin S. Keshner *et al.*
- P115 Sensitivities in Roll-to-Roll Processing of CIGS-Based Photovoltaics on Flexible Metal Foils  
Markus Beck *et al.*

#### **Solar Resource Characterization**

- P116 Progress Toward an Updated National Solar Radiation Data Base  
Steve Wilcox *et al.*
- P117 Workplan and Annex: "Solar Resource Knowledge Management"  
Dave Renné

#### **Communications**

- P118 Planning Strategic Communications and Outreach for the Solar Program  
Susannah Pedigo *et al.*

## Measurements and Characterization

- P119      The FTIR Laboratory in Support of the PV Program  
Brian Keyes *et al.*

## Electrochromic Films

- P120      The Ion Transport and Storage Characteristics of Tungsten and Vanadium Oxide Films  
Deposited by PECVD for Electrochromic Applications  
Mike Seman *et al.*

## **Focus Session: Recombination in Photovoltaic Materials**

**Chairs: Brian Keyes, Dean Levi**

**7:00–9:00 p.m.**

- 7:00      Ribbon Lifetime Issues—Application of Photoluminescence Diagnostics  
Juris P. Kalejs
- 7:20      On the Use of Minority-Carrier Lifetime Measurements: Applying R&D Device-Physics  
Results into Crystalline Si Manufacturing Lines  
Ronald Sinton *et al.*
- 7:40      Lifetime Scanning Using Microwave Reflection Spectroscopy  
George Rozgonyi
- 8:00      Time-Resolved Photoluminescence and Photovoltaics  
Wyatt Metzger *et al.*
- 8:20      Recombination Lifetimes Using the RCPCD Technique: Comparison with Other Methods  
Richard Ahrenkiel *et al.*
- 8:40      Photoexcited Charge Carrier Lifetime Measurements by Time-Resolved Photoluminescence  
Upconversion  
Randy Ellingson

## **Tuesday, October 26, 2004**

*7:30–8:30 a.m., Continental Breakfast*

## **Plenary Session II: Managing the Solar R&D Portfolio—DOE's Systems-Driven Approach**

**Chair: Christopher Cameron**

**8:30–10:10 a.m.**

- 8:30      Systems-Driven Approach: What Is It and Why Do It?  
Christopher Cameron
- 8:40      Benchmarking of Solar Technologies for the Systems Driven Approach  
Charles Hanley
- 9:00      Performance and Cost Model for Solar Energy Technologies in Support of the  
Systems-Driven Approach  
Mark Mehos *et al.*
- 9:20      Solar Technology and Policy Analysis to Support the Systems-Driven Approach  
Robert Margolis .....

- 9:40        The Systems-Driven Approach to Inverter R&D  
Ward Bower
- 9:55        Analyzing Thin-Film Technologies: A Concrete Example Using the Systems-Driven  
Approach  
Ken Zweibel

*10:10–10:30 a.m., Coffee Break*

## **PARALLEL ORAL SESSIONS**

**10:30 a.m.–12:10 p.m.**

### **High-Performance PV II: III-Vs and Concentrators**

**Chairs: Martha Symko-Davies, Robert McConnell**

- 10:30        Development of High Efficiency GaInP/GaInAs/Ge Concentrator Cells and Robust Receiver  
Packages for High-Concentration Photovoltaic Terrestrial Modules  
Raed Sherif *et al.*
- 10:50        Wafer-Scale Fabrication of Ge/Si and InP/Si for Multijunction Solar Cell Applications  
Harry A. Atwater *et al.*
- 11:10        III-V/Si Lattice-Matched Tandem Solar Cells  
John F. Geisz *et al.*
- 11:30        Report on Year 1: Design and Demonstration of a Greater than 33% Efficiency High-  
Concentration Module Using >40% III-V Multijunction Devices  
Vahan Garboushian *et al.*
- 11:50        Characterization of PV Concentrators at NREL  
Keith Emery *et al.*

### **Polycrystalline Thin Films I: CdTe**

**Chair: Ken Zweibel**

- 10:30        XPS and AES Studies of Cu/CdTe(111)-B  
Glenn Teeter *et al.*
- 10:50        Advances in the In-House CdTe Research Activities at NREL  
Timothy Gessert *et al.*
- 11:10        Physics of Large-Area, Thin-Film Devices: Nonuniformities, Interfacial Layers, and  
Reach-Through Effects  
Victor G. Karpov
- 11:30        High-Throughput Processing of Stable CdTe/CdS Solar Cells  
Brian E. McCandless *et al.*
- 11:50        The Intrinsic Stability of CdTe and Cu(In,Ga)Se<sub>2</sub> Polycrystalline Thin-Film Devices  
David S. Albin *et al.*



### **Technology Adoption I**

**Chairs: John Thornton, Charles Hanley**

- 10:30      The Role of Technology Adoption within the Department of Energy's Solar Energy Technologies Program  
John Thornton *et al.*
- 10:50      The Million Solar Roofs Initiative: A Solar Deployment Strategy  
Heather Mulligan
- 11:10      Moving Markets with Education & Outreach Strategies: IREC's Results with Getting the Right Information to the Right People  
Jane Weissman
- 11:30      Native American EmPowerment: Solar Electric Initiatives  
Sandra Begay-Campbell *et al.*
- 11:50      Optimization of Cadmium Telluride Photovoltaic Module Recycling  
Vasilis M. Fthenakis *et al.*
- 12:10–1:40 p.m., *Lunch*  
Speaker: Stephen Forrest, Princeton University  
Tandem, Planar, Bulk and Mixed Heterojunction Solar Cells: Achieving High Efficiencies Using Small Molecular Weight Organic Photovoltaics

### **PARALLEL ORAL SESSIONS**

**1:40–3:40 p.m.**

### **PV Manufacturing R&D I: Manufacturing Support, BOS, and Systems Integration**

**Chairs: Kathryn Brown, Richard Mitchell**

- 1:40      PV Manufacturing R&D Project—Trends in the U.S. PV Industry  
Kathryn Brown *et al.*
- 2:00      Development of an In-line Minority-Carrier Lifetime Monitoring Tool for Process Control during Fabrication of Crystalline Silicon Solar Cells  
Ronald Sinton *et al.*
- 2:20      Interfacial Characterization of Glass Surfaces and Encapsulant Bonding in Thin-Film Photovoltaic Modules  
Hardial Dewan *et al.*
- 2:40      PV Inverter Products Manufacturing and Design Improvements for Cost Reduction and Performance Enhancements  
Ray Hudson *et al.*
- 3:00      The Development and Testing of an AC Module  
Miles Russell
- 3:20      PowerLight Lean Manufacturing—Project Accomplishments  
Jonathan Botkin *et al.*

### **Polycrystalline Thin Films II: CIS**

**Chair: Rommel Noufi**

- 1:40 Properties of High-Efficiency CIGS Thin-Film Solar Cells  
Kannan Ramanathan
- 2:00 CIS Product Line Expansion and Production Scale-up at SSI  
Dale E. Tarrant *et al.*
- 2:20 Processing Improvements for Roll-to-Roll Deposition of Cu(InGa)Se<sub>2</sub>  
Robert Birkmire *et al.*
- 2:40 Solid State Theory of PV Materials: Nanoscale Grain Boundaries and Doping CIGS  
Alex Zunger
- 3:00 Local Built-in Potential on Grain Boundary of Cu(In,Ga)Se<sub>2</sub> Thin Films  
Chun-Sheng Jiang *et al.*
- 3:20 Scanning Tunneling Luminescence and Cathodoluminescence of Grain Boundaries  
in Cu(In,Ga)Se<sub>2</sub>  
Manuel Romero *et al.*

### **Technology Adoption II**

**Chairs: Charles Hanley, John Thornton**

- 1:40 Overview of the Sandia/NREL PV International Activities for the DOE Solar Energy  
Technologies Program  
Vipin Gupta *et al.*
- 2:00 Ten-Year Reliability Assessment of Photovoltaic Water Pumping Systems in Mexico  
Robert Foster *et al.*
- 2:20 Development of a Federal Agency List of Accepted PV Systems for Rural Coops  
Larry Moore *et al.*
- 2:40 Technical Support for Standards and Certification  
Chuck Whitaker *et al.*
- 3:00 The National Impact of Zero Energy Homes  
Thomas Kenney *et al.*
- 3:20 NABCEP Solar PV Installer Certification Program  
Peter Sheehan

3:40–4:00 p.m., *Coffee Break*

### **PARALLEL ORAL SESSIONS**

**4:00–6:00 p.m.**

### **PV Manufacturing R&D II: Manufacturing**

**Chairs: Richard Mitchell, Kathryn Brown**

- 4:00 Large-Scale PV Module Manufacturing Using Ultra-thin Polycrystalline Silicon Solar Cells  
John Wohlgemuth *et al.*

- 4:20 EFG Technology and Diagnostic R&D for Large-Scale PV Manufacturing  
Juris Kalejs
- 4:40 Advances in String Ribbon Silicon Technology  
Jack Hanoka
- 5:00 ECD's PV Manufacturing R&D Program: The Implementation of a Comprehensive Online Diagnostic System for Roll-to-Roll a-Si Solar Cell Production  
Tim Ellison *et al.*
- 5:20 Recent a-Si Manufacturing Developments at Energy Photovoltaics, Inc.  
Hermann Volltrauer *et al.*
- 5:40 Manufacturing Process Advancements for Flexible CIGS PV on Stainless Foil  
Scott Wiedeman *et al.*

### **Balance of Systems**

**Chair: Ward Bower**

- 4:00 Progress of Photovoltaic BOS R&D and Related Electronic Hardware Analysis  
Ward Bower
- 4:20 High-Reliability Inverter Project  
Ray Hudson *et al.*
- 4:40 General Electric's High-Reliability Photovoltaic Inverter Program  
Joseph Smolenski
- 5:00 SatCon's High-Reliability Inverter Initiative  
Leo Casey
- 5:20 Coordination of Long-Term Inverter Testing  
Jerry Ginn
- 5:40 Inverter Testing and Analysis at Sandia National Laboratories  
Sigifredo Gonzalez *et al.*

### **PV Systems Engineering and Reliability**

**Chair: Michael Quintana**

- 4:00 Photovoltaic Systems Engineering and Reliability; Overview  
Michael Quintana *et al.*
- 4:05 NREL PV System Performance and Standards Technical Progress  
Carl Osterwald *et al.*
- 4:20 Changes in the 2005 National Electrical Code and Their Impact on the PV Industry  
John Wiles
- 4:40 Photovoltaic Power Plant Experience at Arizona Public Service—A 5-Year Assessment  
Larry Moore *et al.*
- 5:00 Benchmarking Results for Utility-Scale PV Systems  
Andy Rosenthal

5:20 Recent and Planned Enhancements for PVWATTS  
Bill Marion *et al.*

**Focus Session: Systems-Driven Approach**

**Chair: Christopher Cameron**

**7:00–9:00 p.m.**

**Wednesday, October 27, 2004**

*7:30–8:30, Continental Breakfast*

**Plenary Session III: Program Highlights**

**Chairs: Tom Surek, Joe Tillerson**

**8:30–10:10 a.m.**

- 8:30 Photovoltaics R&D: At The Tipping Point  
Larry Kazmerski
- 8:50 From Microscale to Macroscale: PV Systems of the Future  
Jeffrey Nelson
- 9:10 Progress in Thin-Film CdTe Module Manufacturing  
Rick C. Powell *et al.*
- 9:30 A Vision for Crystalline Silicon Solar Cells  
Richard Swanson
- 9:50 Approaches for Ultra-High Efficiency Solar Cells  
Christiana Honsberg

*10:10–10:30 a.m., Coffee Break*

**PARALLEL ORAL SESSIONS**

**10:30 a.m.–12:10 p.m.**

**Silicon I: Crystalline**

**Chair: Howard Branz**

- 10:30 a-Si:H Emitter and Back-Surface-Field Contact for Crystalline Silicon Solar Cells  
Tihu Wang *et al.*
- 10:50 Development of High-Efficiency Solar Cells on Low-Cost Silicon Materials  
Ajeet Rohatgi *et al.*
- 11:10 The Impact of Metal Impurity Clusters on Solar Cell Performance in Multicrystalline Silicon  
Eicke R. Weber *et al.*
- 11:30 Effect of Grown-in Light Element Impurities on PV Silicon Mechanical Properties  
Abdennaceur Karoui *et al.*
- 11:50 Residual Stress Measurements as Related to Solar Cell Processing  
Steven Danyluk *et al.*

## **Exploratory PV II: Advanced Solar Conversion Processes**

**Chair: Robert McConnell**

- 10:30 DOE Office of Science Funded Basic Research at NREL that Impacts Photovoltaic Technologies  
Satyen K. Deb
- 10:50 High-Efficiency Solar Cell Concepts: Physics, Materials, and Devices  
Angelo Mascarenhas *et al.*
- 11:10 Theory and Experimental Investigation of Approaches to >50% Solar Cells  
Christiana Honsberg *et al.*
- 11:30 Quantum Dot Solar Cells: High Efficiency through Impact Ionization  
Mark Hanna *et al.*
- 11:50 Quantum Dots for PV: Theory  
Alex Zunger

## **Concentrating Solar Power I**

**Chair: Thomas Mancini**

- 10:30 Development and Testing of High-Temperature Solar Selective Coatings  
Cheryl Kennedy *et al.*
- 10:50 Development and Testing of Solar Reflectors  
Cheryl Kennedy *et al.*
- 11:10 Advanced Heat Transfer and Thermal Storage Fluids  
Dan Blake *et al.*
- 11:30 Concentrator Optical Characterization  
Timothy Wendelin
- 11:50 Economics of CSP Deployment  
Henry Price *et al.*

*12:10–1:40 p.m., Lunch*

Speaker: Charles Korman, GE Global Research  
Vision of GE Energy

## **PARALLEL ORAL SESSIONS**

**1:40–3:40 p.m.**

## **Silicon II: Thin Films**

**Chair: J. David Cohen**

- 1:40 Amorphous and Nanocrystalline Silicon PV Technology  
Jeffrey Yang *et al.*
- 2:00 Fabrication, Analysis and Modeling of High-Efficiency a-Si Based Solar Cells  
Xunming Deng
- 2:20 Insights from Modeling and Mobility Measurements in Amorphous and Microcrystalline Silicon Solar Cells  
Steluta Dinca *et al.*

- 2:40 Lowgap Hot-Wire a-SiGe:H Materials and Devices  
Harv Mahan *et al.*
- 3:00 Phase Engineering of High-Efficiency a-Si:H Solar Cells  
Christopher Wronski *et al.*
- 3:20 Tritiated Amorphous Silicon: Insights into the Staebler-Wronski Mechanism  
Paul Stradins *et al.*

#### **PV Module Reliability**

**Chair: Roland Hulstrom**

- 1:40 PV Module Reliability R&D Project Overview  
Roland Hulstrom *et al.*
- 2:00 Performance Degradation Rates in Commercial Modules  
David King *et al.*
- 2:20 Outdoor Monitoring and High-Voltage Bias Testing of Thin-Film PV Modules  
Neelkanth Dhere *et al.*
- 2:40 Module Design, Materials, and Packaging Research Team: Activities and Capabilities  
Thomas J. McMahon *et al.*
- 3:00 Packaging Materials and Design for Improved Module Reliability  
Gary Jorgensen *et al.*
- 3:20 Module Encapsulant Diagnostics and Modeling  
Michael Kempe

#### **Concentrating Solar Power II**

**Chair: Mark Mehos**

- 1:40 Advanced Trough Concentrator Design  
Randy Gee *et al.*
- 2:00 Parabolic Trough Organic Rankine Cycle Solar Power Plant  
Scott Canada *et al.*
- 2:20 Rotating Platform Testing Development  
Timothy Moss *et al.*
- 2:40 Trough Thermal Storage Developments  
Douglas Brosseau *et al.*
- 3:00 Dish Stirling Development  
Chuck Andraka *et al.*
- 3:20 Siting Utility-Scale CSP Projects  
Mark Mehos *et al.*

3:40–4:00 p.m., *Coffee Break*

## **Poster Session II**

**4:00–6:00 p.m.; Reception @ 5:00 p.m.**

### **Technology Adoption**

- P002      21-kW Thin-Film PV Technology Validation—An NREL-Solar Energy Center Cooperative Project  
Peter McNutt *et al.*
- P004      The Design of a Net-Metering and PV Exhibit for the 2005 Solar Decathlon  
Michael Wassmer *et al.*
- P006      Cooperation with Brazil for Sustainable Rural Development  
Alia Ghandour
- P008      Cooperation with China for Sustainable Rural Energy Development  
Ian Baring-Gould *et al.*
- P010      Environmental Impact Assessment for Materials in the Production of Cu(InGa)Se<sub>2</sub> Photovoltaics  
Vasilis M. Fthenakis *et al.*
- P012      Development of a Home Energy Monitor  
Robb Aldrich *et al.*
- P014      Complementing Energy Efficiency with PV  
Gabriela Cisneros *et al.*
- P016      Rural Energy Options Analysis Training Development and Implementation at NREL  
Paul Gilman *et al.*
- P018      Solar Decathlon 2005  
Cecile Warner *et al.*
- P020      Outreach is Serious Fun!  
Wendy Larsen
- P022      Using NREL's HOMER Micropower Optimization Model to Compare Solar, Diesel, and Hybrid Off-Grid Power Systems  
Peter Lilienthal *et al.*
- P024      IEA-PV Power Systems Task 10—Urban Scale PV Applications, Urban Energy Solutions for the Emerging Global Market  
Christy Herig
- P026      Small Hybrid Systems and Applications Testing at NREL's Outdoor Test Facility  
Lorenzo Roybal
- P028      Five-Year Reliability Assessment of SunWize PV Systems in Mexico  
Robert Foster *et al.*
- P030      Identifying Key Issues in Implementing a Quality Solar for Schools Program  
Jennifer S. Szaro *et al.*

### **PV Manufacturing R&D**

- P032      Manufacturing Process Advancements for Flexible CIGS PV on Stainless Foil  
Lin Simpson *et al.*
- P034      Enhanced CIS Production Using XRF for PVD Process Control  
Dale Tarrant *et al.*
- P036      Development of Automated Production Line Processes for Solar Brightfield Modules  
Michael Nowlan *et al.*
- P038      Silicon-Film Sheet Material  
Jim Rand *et al.*
- P040      PVMR&D Overview  
Kathryn Brown *et al.*

### **Balance of Systems**

- P042      Outdoor Performance Characterization of Residential Grid-Connected Inverters  
Kevin Lynn
- P044      Inverter Long-Term Test Facility—Early Results  
Corey Asbill

### **PV Systems Engineering and Reliability**

- P046      Advances in Solar Radiometry and Metrology  
Daryl Myers *et al.*
- P048      Certification of PV Modules and Systems and IEC Participation  
Steve Chalmers
- P050      Management and Administration of IEC TC-82 Secretariat  
Howard Barikmo

### **PV Module Reliability**

- P052      Alternative Approaches to Buss Bars for PV Modules  
Joel Pankow
- P054      NREL PV Module Reliability and Performance R&D Status and Accomplishments  
Carl Osterwald *et al.*
- P056      Advanced Indoor Module Light-Soaking Facility  
Joseph del Cueto *et al.*
- P058      Outdoor Energy Rating Measurements of PV Modules  
Yingtang Tang *et al.*
- P060      PV Module Durability Research and Module Long-Term Exposure  
Neelkanth Dhere *et al.*



## Silicon

- P062 Inkjet Based Metallizations for Solar Cells  
Tanya Kaydanova *et al.*
- P064 Growth of High Minority Lifetime Epitaxial and Polycrystalline Silicon by Hot Wire Chemical Vapor Deposition  
Harry Atwater *et al.*
- P066 Acoustical Diagnostics of Residual Stress in EFG Silicon Wafers  
Anton Belyaev *et al.*
- P068 Hydrogenation Methods and Passivation Mechanisms for c-Si Photovoltaics  
Stefan K. Estreicher *et al.*
- P070 Hydrogen-Defect Interaction Phenomena in Si  
S. Ashok *et al.*
- P072 The Role of Hydrogen in Metastable Defect Formation in a-Si:H and a-Ge:H  
P. Craig Taylor *et al.*
- P074 Electronic Properties of RF Glow Discharge Microcrystalline Silicon Near the Amorphous Silicon Phase Boundary  
Dave Cohen *et al.*
- P076 Species Responsible for Amorphous Silicon Growth and Properties in Photovoltaics  
Alan Gallagher *et al.*
- P078 Correlation of Material Properties and nc-Si:H Solar Cell Performance Studied by Raman and Photoluminescence Spectroscopies  
Keda Wang *et al.*
- P080 Physics of Nanocrystalline Si Solar Cells  
Vikram Dalal *et al.*
- P082 Four-Terminal Solar Cells Using Ultra-Thin Amorphous Silicon and Nanocrystalline Si  
Jian Hu *et al.*
- P084 Structure of HWCVD Amorphous-SiGe:H Thin Films  
Don Williamson *et al.*
- P086 Thin-Film Si Solar Cells and Materials by Single-Chamber PECVD and HWCVD  
Yuan-Min Li *et al.*
- P088 Transparent Conductive Oxide Materials for Improved Back Reflector Performance for Amorphous Silicon-Based Solar Cells  
Scott J. Jones *et al.*
- P090 Real-Time Spectroscopic Ellipsometry as an In-Situ Diagnostic for HWCVD Growth of Amorphous and Epitaxial Si  
Dean Levi *et al.*
- P092 Reflectance Spectroscopy: Rapid Quantitative Measurements in Commercial Production of Si Solar Cells  
Bhushan Sopori

P094	SiN:H Processing for Fire-Through Metal Contacts and Hydrogen Passivation: Investigations Toward a Coherent Understanding Bhushan Sopori <i>et al.</i> .....
P096	Photovoltaic Properties of Nanocrystalline Germanium-Carbon:H Alloys Xuejun Niu <i>et al.</i> .....
P098	High-Rate Deposition of Hydrogenated Nanocrystalline Silicon Solar Cells Baojie Yan <i>et al.</i> .....
P100	Nanocrystalline and Microcrystalline Silicon—Simulations of Improved Material Properties Rana Biswas <i>et al.</i> .....
P102	Three-Dimensional Void Array Photonic Crystal Backside Reflector for Efficient Light Trapping in Thin-Film Crystalline Silicon Solar Cells David T. Danielson <i>et al.</i> .....
P104	Metallo-Dielectric Photonic Crystal Tunable Narrowband Infrared Sources Irina Puscasu <i>et al.</i> .....
P106	Stress-Induced Lifetime Variations in Rapid Thermal Processed Silicon Wafers Abdennaceur Karoui <i>et al.</i> .....
P108	Hot-Wire Chemical Vapor Deposition of Silicon Nitride for Photovoltaic Applications Harry Atwater <i>et al.</i> .....

**Focus Session: Peer Review**

**Chairs: Jeffrey Mazer, Kevin DeGroat**

**7:00–9:00 p.m.**

**Thursday, October 28, 2004**

*7:30–8:30 a.m., Continental Breakfast*

**Chair: Robert Margolis**

**Plenary Session IV-A: Solar Future**

**8:30–10:00 a.m.**

8:30	The Solar Future for the United States to 2050 Robert Margolis
9:00	The New U.S. PV Industry Roadmap Allen Barnett
9:20	Concentrating Solar Power: Where We Are and Where We Are Going Claudine Schneider
9:40	Growing Prospect for Solar Hot Water Bill Guiney

*10:00–10:20 a.m., Coffee Break*

**Plenary Session IV-B: Solar Future**

**Chair: Robert Margolis**

**10:20–11:50 a.m.**

- |       |                                                                                      |
|-------|--------------------------------------------------------------------------------------|
| 10:20 | The Regulatory and Policy Context for Moving Solar into the Mainstream<br>Tom Starrs |
| 10:40 | Engaging the Financial Community<br>Julie Blunden                                    |
| 11:00 | The Potential Impact of Solar on Job Creation and the Environment<br>Daniel Kammen   |
| 11:20 | PANEL Q&A<br>Moderator: Robert Margolis                                              |

**Review Meeting Wrap-Up**

- |       |           |
|-------|-----------|
| 11:50 | Tom Surek |
|-------|-----------|

MONDAY			TUESDAY			WEDNESDAY			THURSDAY		
PLENARY Opening Session I 8:30-9:50 AM <ROOM>			PLENARY Systems-Driven Approach 8:30-10:10 AM <ROOM>			PLENARY Program Highlights 8:30-10:10 <ROOM>			PLENARY Solar Future I 8:30-10:00 AM <ROOM>		
Coffee Break 9:50-10:20			Coffee Break 10:10-10:30 AM			Coffee Break 10:10-10:30			Coffee Break 10:00-10:20 AM		
PLENARY Opening Session II and Rappaport Award 10:20 AM-12:10 PM <ROOM>			High Perf. II: III-V & conc CdTe Technol. Adoption I 10:30 AM-12:10 PM <ROOM> <ROOM> <ROOM>			Silicon I: crystalline Exploratory II Conc. Solar Power I 10:30 AM-12:10 PM <ROOM> <ROOM> <ROOM>			PLENARY Solar Future II 10:20-11:50 AM <ROOM>		
LUNCH 12:10-1:40 PM SPEAKER: Nate Lewis, CalTech Sustainable Energy			LUNCH 12:10-1:40 PM SPEAKER: Steve Forrest, Princeton Organic Photovoltaics			LUNCH 12:10-1:40 PM SPEAKER: Charles Korman, GE Energy GE Energy - Vision			Wrap-Up 11:50 AM-12:00 PM		
HighPerf. I: thin films	Exploratory I	Solar Heat and Light	PV Manuf. R&D I	CIS	Technol. Adoption II	Silicon II: thin film	Module Reliability	Conc. Solar Power II			
--- 1:40-3:40 PM --- <ROOM> <ROOM> <ROOM>			--- 1:40-3:40 PM --- <ROOM> <ROOM> <ROOM>			--- 1:40-3:40 PM --- <ROOM> <ROOM> <ROOM>					
Coffee Break 3:40-4:00 PM			Coffee Break 3:40-4:00 PM			Coffee Break 3:40-4:00 PM					
POSTERS/RECEPTION High Perf., Exploratory, CIS, CdTe, Solar Heat&Light, Misc 4:00-6:00 PM (reception @ 4:45 PM) <ROOM>			PV Manuf. R&D II Balance of Systems PV Sys.Eng. Reliability --- 4:00-6:00 PM --- <ROOM> <ROOM> <ROOM>			POSTERS/RECEPTION Silicon, Tech Adopt., PVMR&D, BOS, PV Sys.Eng. Reliab., Module Reliab. 4:00-6:00 PM (reception @ 4:45 PM) <ROOM>					
FOCUS SESSION Recombination in PV Materials 7:00-9:00 PM <ROOM>			FOCUS SESSION Systems-Driven Approach 7:00-9:00 PM <ROOM>			FOCUS SESSION Peer Review 7:00-9:00 PM <ROOM>					